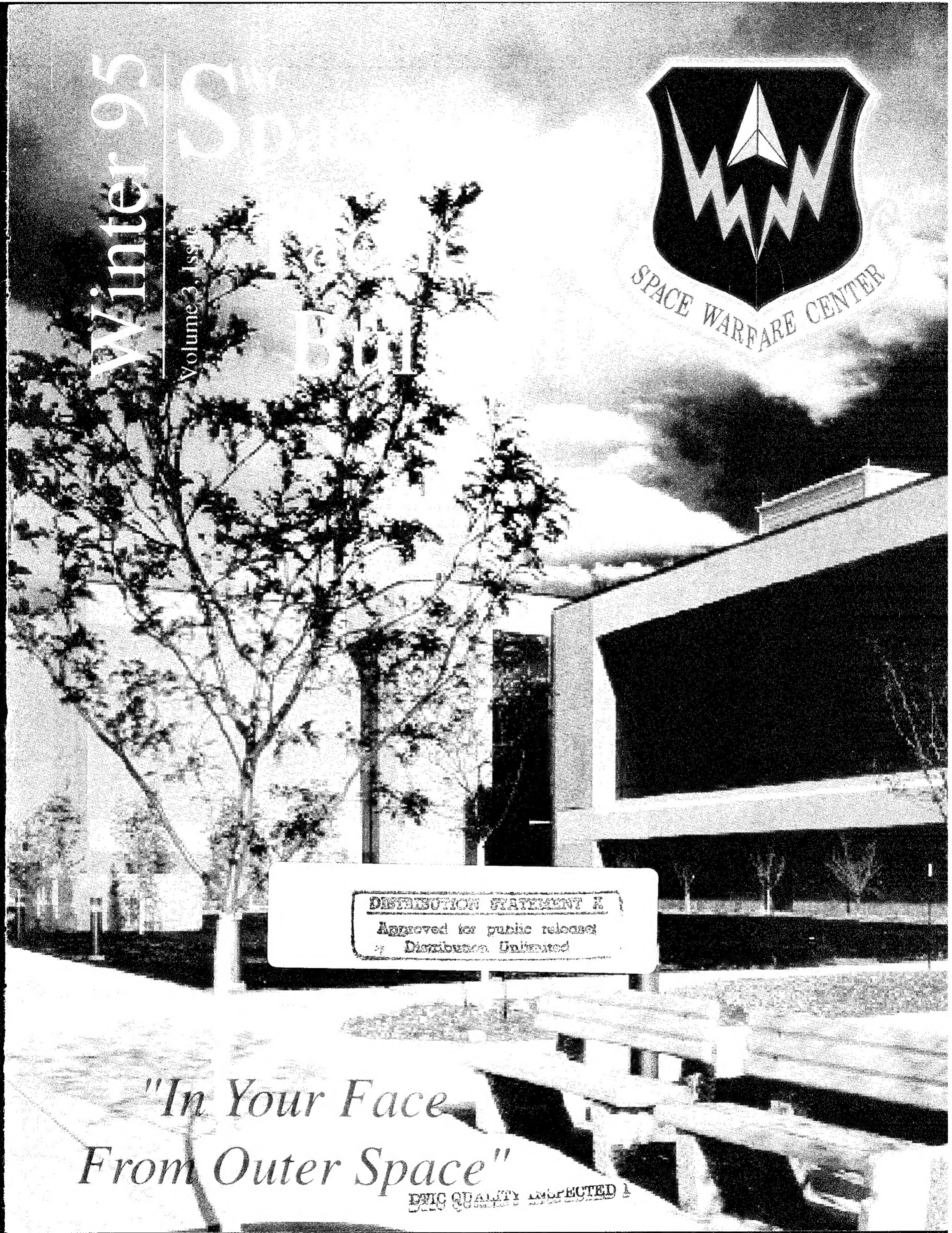
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The Space Tactics Bulletin
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The Space Tactics Bulletin is an official, nondirective SWC publication. Its purpose is to update warfighting staffs and units on SWC efforts to effectively employ space assets in support of operations, and provide a forum for information exchange to improve space tactics and procedures. The views and opinions expressed herein, unless otherwise specifically indicated, are those of the individual author. They do not purport to express the views of the Commander, Space Warfare Center, the Department of the Air Force, or any other department or agency of the United States Government.

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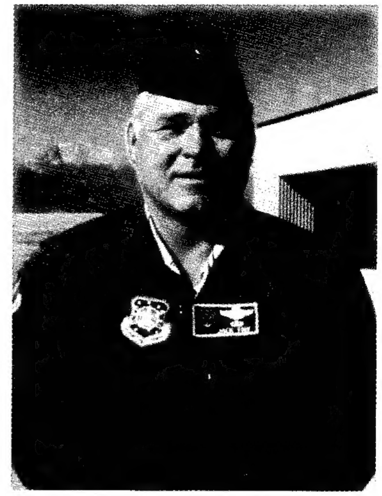


COMMANDER'S CORNER

In my last column I said that the hallmark of the Space Warfare Center has been and continues to be change. In keeping with that tradition, I will address our recent and upcoming changes to both mission and organization. I want to emphasize that, although it appears we are in constant flux, we continue with our daily mission to support the warfighter.

My first priority in this article is to issue a hearty welcome to the men and women of the 576th Flight Test Squadron. As of 22 February, the 576th became the newest addition to our organization. I expect many issues to arise as we learn to work together; but, I want to assure everyone that the merging of our organizations will make both stronger. Our customers will see no change in the high level of service they have grown accustomed to.

In the last space bulletin I mentioned that, with the addition of the 576th, we would become the Space and Missile Warfare Center. We have since received new direction. Although our mission will change to reflect the incorporation of the 576th, our name will remain the same. We will continue to be known as the Space Warfare Center.

The newest change to the SWC mission comes out of our DO organization. Our Space Tactics School has been such a success that it will be incorporated into the Air Force Weapons and Tactics School at Nellis AFB this summer. As of July, the school will move to Nellis with the first class consisting of the initial cadre of instructors. I want to emphasize that only the location is changing. Expect the same high level of quality you have become accustomed to.

This issue has many interesting articles on a myriad of space activities including a short article on the 76th SOPS activation and an article on the aforementioned Space Tactics School. These will provide you with the latest space information, as will all of the articles. As always, I solicit your comments to help us continue to improve our bulletin.

My final issue for this edition of the Commander's Corner is to bid everyone of our customers and co-workers a fond farewell. As of 18 March, Brigadier General Glen W. Moorhead III will be the new SWC Commander. I want to thank everyone for their support throughout these past two years. I know you will provide the same level of support to the new commander as you have given me. To those of you in the Air Force I've had the privilege of working with and commanding in previous assignments - it's been a great honor. Thank you for your contributions to the Air Force and our nation.

Keep in touch—Fryjack (TIGER 01, SABER 01, SWC/CC)

Howard J. Fry

HOWARD J. FRY, JR.
Colonel, USAF
Commander

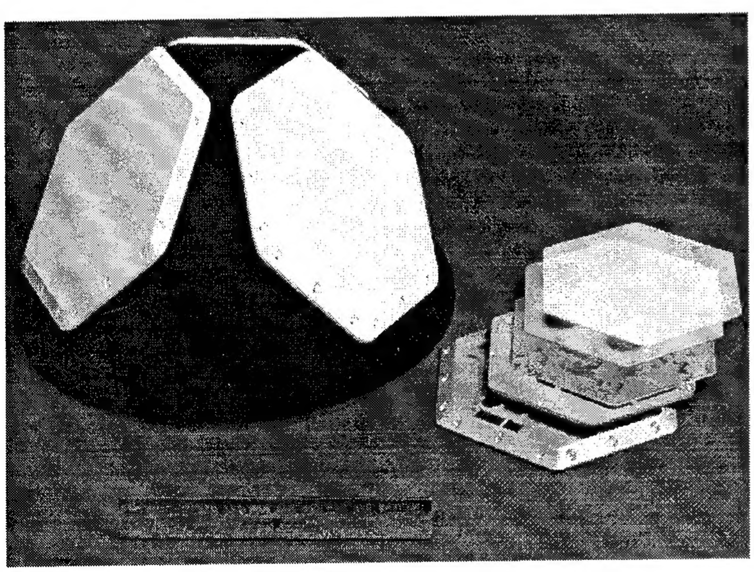
PROJECTS ANTENNA AND ADVANCED COMMUNICATIONS BRING SPACE TO THE WARFIGHTER

Major Jon Sercel, SWC/XRI, DSN 560-9680

Coalition forces negated Saddam's ground forces and achieved air supremacy in the Persian Gulf Conflict primarily because they were able to move information and forces when and where needed to put superior power in coalition forces hands. Fortunately, our force structure had adequate time to build up the Southwest Asia Area of Responsibility (AOR) to make this happen. It is still an important dictum that air supremacy requires timely information at the right places and at the right time in order to be effective. Within the approved Theater Battle Management Architecture, ACC's Theater Air Control System (TACS) is the mechanism we use today to control Air Forces. TACS encompasses manpower, equipment and doctrine which will all have to adapt to support force modernization efforts as they enter the twenty-first century. What this will encompass is the ability to collect, disseminate and synthesize vast amounts of information into tailored bits of information a deployed combat force can use, no matter where they go, to overcome an enemy force.

US and Air Force Space Commands have embarked on an effort, in concert with other communities of interest, to develop high data-rate, global broadcast, satellite-based information systems to help satisfy this need. These efforts include increasing data flows to both warfighting echelons and ultimately the warfighter himself. To make this capability a reality, a bi-directional, secure, full duplex, high data-rate communications architecture must be incorporated into all our warfighting infrastructures, in order to realize full combat potential.

Today there is a gap between fielded capabilities and tomorrow's goal of complete, tailored information to warfighters in the field. At the Space Warfare Center (SWC), Projects Antenna and Advanced Communications are working to fix that deficiency. These projects are focused at developing prototype radio frequency (RF) hardware and architecture solutions as part of proof-of-principle/proof-of-concept demonstrations. The results of Projects Antenna and Advanced Communications will help drive requirements definitions for a final, operationally driven architecture providing both Air Force and DOD with solutions to high data-rate information flow to and from warfighters.



Proof of concept conformal TDRSS airborne capable antenna

Project Antenna is a four-phase SWC and SAF effort that began in late 1994. This project is developing a cost-effective, high data-rate satellite communications capability usable by combat air forces. Phase one began as a coordinated effort with National, ACC, AMC, and AFSOC. ACC/DR approved our gameplan to determine whether a small conformal antenna could be developed to support ACC's stated Real Time Information into/out of the Cockpit (RTIC/RTOC) requirement. This phase culminated with a detailed study and a cost benefit report of possible assets, technologies, and architectures that we could use to provide the tailored volume of information for combat platforms. Coordination with SWC, National, ACC, AMC and AFSOC staffs resulted in an agreement to proceed to the next phase. ACC/DR then provided the SWC with USAF test assets from the 413 Flight Test Group at Edwards Air Force Base.

Phase two began the actual development and ground testing of a prototype antenna for an NC-130 test aircraft. C-130 aircraft integration engineering began to ensure aircraft flight safety, as well as form and functionality of the antenna radio suite, for the selected platform was attainable. Plausible applications such as AFTENCAP's TALON SPECTRUM Multi-Spectral Imagery (MSI) products were also investigated for use in demonstrating the antenna's capabilities in the planned proof-of-principle demonstration. Phase two culminated with successful engineering demonstrations of a stand-alone antenna-radio suite at the developer's location and a decision to proceed with actual aircraft integration and flight tests.

This spring concludes phase three of our effort when we demonstrate this technology in an airborne demonstration. This phase will use existing world-wide, national communications assets and move imagery/ information directly from a notional producer to an enroute airborne aircraft. AMC and AFSOC are interested in utilizing this capability once successfully demonstrated.

Phase four will then begin this year and culminate in FY96/7, with the development of a return link/ transmit capability. A driving operational concern will be the migration of this technology to USAF standard radios and emerging communications standards. Integrating Project Antenna's technology with developing information processing (Real Time Symmetric Multi-Processor (RTSMP)) technology is also a desired goal during this phase. The benefit of this technology to the warfighter will be an ability today to have improved, two-way, world-wide higher data-rate communications on nationally-owned communications architectures, and is an interim capability to the envisioned two-way Global Broadcast System demonstrated during JWID 95.

In partnership with other SWC efforts, Project Advanced Communications investigates new technologies for secure, jam resistant, high data rate, wireless Local Area Networking (LAN) and communications technologies. This effort will ultimately support the Space Warfare Center's future envisioned satellite-based communications architecture. Linking warfighters directly to the information and decision-making processes to make them more effective in combat is what the SWC is all about. When taken as part of a whole architecture, these projects can be the near-term mechanism by which we fulfill better information to warfighters at all levels until a final, fully integrated national architecture is available to provide these services.

MILSTAR COMMUNICATIONS: A NEW RESOURCE FOR THE WARRIOR

Lt Col Ralph McLain, HQ AFSPC/SCZ, DSN 692-5076

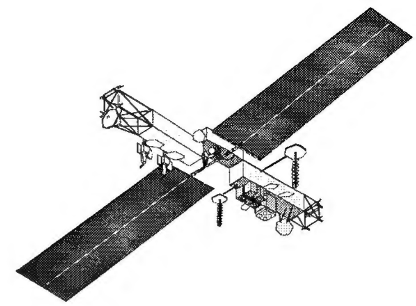
On the afternoon of 7 Feb 94, a huge Titan 4 rocket roared into the clear blue sky over Florida's Cape Canaveral AFS. The billion dollar Milstar communications satellite in this rocket's nose marked the beginning of a new era of warfighter information capability. The dramatic early morning launch of the second Milstar on 5 Nov 95 continued this story.

Milstar provides highly jam-resistant, survivable, and enduring military satellite communications, known in the trade as MILSATCOM. It will meet the minimum essential command and control requirements of tactical military forces, as well as those of the National Command Authority and the strategic community, well into the next century. Its use of extremely high frequency radio transmissions and advanced digital techniques ensures a high degree of survivability under the conditions of modern warfare. The Milstar System Operational Management Office in AF Space Command establishes system-level communications policy which is implemented by the Milstar Operations Center at Falcon AFB, CO. The principal users of the system, the Unified CINCs, can directly task the constellation to fulfill their communications needs, providing vital protected connectivity for the entire DoD.

Most present satellite communications systems are transponders—the payload simply broadcasts back to

earth what it hears in each communications channel. Circuit connectivity must be provided on the ground. By contrast, each Milstar satellite is an "antenna farm in the sky" with an internal circuit switch that provides unparalleled flexibility.

The first two satellites can carry low speed data (about a page of text every 10 seconds) and secure voice circuits. The next four Milstar satellites, which will be launched starting in 1998, will distribute data at speeds up to slow scan TV signals as well. Milstar satellites have an on-board resource controller, the brain of the communications payload. This controller receives service requests from user terminals, assigns resources to communications networks and activates them at user demand. Milstar users, the warfighters, can define their connectivity needs in real time and then change circuit configurations as the operational situation dictates.



In addition to jam resistance and user control, Milstar has another feature unique in any MILSATCOM system: crosslinks. Specialized antennas on each end of the spacecraft allow the payloads to talk to each other directly, eliminating the need for vulnerable ground stations. Using crosslinks, world spanning networks will be possible without the use of earth surface relay nodes.

The second satellite is currently undergoing qualification testing. If all goes according to plan, the crosslink radios will be activated shortly, and the first transmission, a message from the Chairman of the Joint Chiefs of Staff, will flow from the Pentagon to our forces across the U.S. and the Pacific Ocean. This first technological handshake in space through a Milstar crosslink reflects the information age advances our warfighters will use as they protect America's vital interests around the world.

ON ALERT: AF'S FIRST THEATER MISSILE WARNING UNIT STANDS GUARD AGAINST MISSILE THREAT

SSgt. Brian Orban, HQ AFSPC Public Affairs

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They consider themselves living on the edge of the envelope.

Less than two years ago, their organization was still a concept drawn up as one of the lessons learned from the Gulf War — a need to accurately detect and report short-range ballistic missiles as a way to counter this increasing threat.

That concept is now reality. The 11th Space Warning Squadron, based at Falcon AFB, Colo., has become the Air Force's first squadron dedicated specifically to detecting these short-range "theater" missiles.

"Eighteen months ago, there was no dedicated theater missile warning," said Lt. Col. Darrell Herriges, 11th SWS commander. "But what we continue to see today is the threat developing in that arena. Theater class missiles are becoming more prevalent around the world. That's why we're here today."

Fully operational since March, the 11th's early warning system uses data from the constellation of Defense Support Program satellites in geosynchronous orbit 22,000 miles above the earth. The satellite data is processed by the 11th's battery of ONYX mainframe computers, which processes the data in near realtime so the squadron can get the warning out to warfighters around the world.

Going from a prototype unit to fully operational "changed the lives of our operators," Colonel Herriges said. "From that moment forward, there was no time to relax. As we try to improve our systems, train our people and make changes and additions to our equipment, at the forefront of our minds is that operations must continue. So, we have a challenge in the squadron — we are still improving yet we have live operations."

That's part of the responsibility that comes with living on the edge of the envelope, the colonel added.

"We're bringing in every bit of information we can out of the DSP system," said Chief Master Sgt. Randy Edwards, superintendent of operations for the 11th SWS.

The reason theater class missiles are so threatening "is because it's difficult to see them and figure out where they came from," Colonel Herriges said. These missiles have a short flight time, so speed is the key to finding them and alerting warfighters.

To improve this detection and response rate, the squadron prides itself on the quality of training, Colonel Herriges said.

"Our approach has been to take a cooperative team approach to find the best practices in all areas of our business, and minimize any broad sweeping changes so we can come up with the best way of doing business and fine tune it after that," said Maj. Jeff Maddox, 11th SWS operations officer.

Since March, the squadron has responded to more than 60,000 events generated by the computer, some real and some false. It's the operator's job to make that distinction.

"Those judgments are being made by captains, lieutenants and technical and staff sergeants out there on the operations floor. Our crews have misidentified less than a handful of these events. That captures the quality and caliber of the people we have in our squadron," Chief Edwards said.

"You have to make a lot of command decisions on the operations floor every day on every shift," Colonel Herriges said. "So the potential to make an error is tremendous. However, the fact that we make very few errors explains why I'm proud of the training and certification of our crew members."

"It's a teamwork approach. It takes that crew out there working together to make it happen," Major Maddox said.

THEATER BALLISTIC MISSILE PARAMETER CALIBRATION

Mr Luther Briggs, SWC/AET, DSN: 560-9090
Dr Albert Bevan, SWC/AET, DSN: 560-9365
Lt Col Martin Remedes, SWC/CCA, DSN: 560-9067

Imagine, off the pages of a Tom Clancy novel, a special operations team hitting a hostile, rocky beach to provide a known ground reference point for space sensors monitoring theater ballistic missile launches. They carry a twenty-three pound LLYNX-Eye laser calibration system, the newest little wonder of the Space Warfare Center (SWC). Set up time is brief and they are transmitting in four minutes, flat.

The year is . . . 1996!

A recent scientific breakthrough was achieved by Lawrence Livermore National Laboratory (LLNL) in building a compact laser to calibrate space sensors. LLNL has developed a small, lightweight, and easily transportable solid state laser that is side pumped and uses micro-channel cooled diode laser bars for high efficiency. This laser, LLYNX-Eye, will make it possible to enhance space sensor data for direct tactical applications in the very near future. The design challenge for LLNL was to develop a compact laser of sufficient power to reach through the atmosphere into space, and also operate at a wavelength in the sensitive regime of the space sensor. For field deployment models, tactical considerations demand a lightweight sealed ruggedized unit that will self-tune and self-align. This is under development in FY-96 and 97.

Often satellites provide our first indication of theater ballistic missile

launches. The line-of-sight accuracy of these space sensors can be significantly improved through calibration using a very bright source providing a known ground reference point. Such a beacon, LLYNX-Eye, could be used in conjunction with the U. S. Air Force's Talon Shield/Alert and the Army's Joint Tactical Ground Station (JTAGS). Test plans are being developed to evaluate the effectiveness of this calibration method and the dependence on such things as geometry, time since last calibration, and error budget allocation.

This LLYNX-Eye laser calibration system represents an emerging technology under a fast-track development—sponsored by SWC working with the Space and Missile Center (SMC)—that will impact directly on existing and future spaceborne sensor platforms. It is an excellent example of how cooperation among Government laboratories, directed by the SWC, can lead to theater applications of leading-edge LLNL technology to support the warfighter.

To demonstrate the tactical use of theater benchmarking for space sensors, a series of demonstrations will be conducted in FY-96 and FY-97, known as the Gunfighter series. This series of tests will blend the warfighter's ideas into the development of a useable operational design. Joint CONUS exercises will be supported with missile event data in conjunction with calibrated satellite data.

THEATER BALLISTIC MISSILE EXERCISE SUPPORT

LCDR Rob Vaughan, HQ USSPACECOM/J33OW, DSN 692-5084

The proliferation of Theater Ballistic Missiles (TBM) allows just about any belligerent the ability to launch an attack against its neighbor. Although these weapons are not very accurate, they are relatively cheap, can have a significant psychological effect, and can disrupt operations, especially when combined with chemical warheads. Naturally, warfighters need accurate and timely warning of a TBM attack. The Theater Event System (TES) provides this warning using both data and voice.

Like any warfare area, active and passive Theater Missile Defense (TMD) and attack operations need to be exercised rigorously and regularly. Working with US Space Command, theater exercise planners can develop scenarios to train their warfighters by following the eight easy steps below:

STEP 1: Determine your exercise objectives and the enemy order of battle. Is the objective to train active/passive defense measures or attack operations? Regarding order of battle, what type of TBMs does the enemy possess (SCUD B or SCUD C, for example)? How many TBMs and Transporter/Erector/Launchers (TELs) do they have? Where are the TEL launch, hide, and reload sites located?

STEP 2: Develop your TBM launch script. Determine launch location (latitude/longitude), launch time (Zulu), launch azimuth (degrees true), range (nautical miles or kilometers), impact location (latitude/longitude), and missile type.

STEP 3: Determine the method and rules for providing voice warning. How will voice warning be disseminated to troops in the field? Will warning be provided to countries at risk, cities at risk, or sectors at risk? What charts will be used?

STEP 4: Provide information from Steps 2 and 3 to US Space Command through the Joint Space Support Team (JSST) or by calling one of the points of contact below:
(719) 554-XXXX, DSN 692-XXXX
ACOM, SOUTHCOM, STRATCOM: LCDR Rob Vaughan, USN, -5084
EUCOM: MAJ Bruce MacNeill, USA, -3666
PACOM: LTC Joe Torres, USA, -6903
CENTCOM: MSGT Barry Rainwater, USAF, -5460

STEP 5: US Space Command provides the appropriate TES elements the information from Steps 2 and 3 and coordinates the exercise with the Missile Warning Center (MWC)

STEP 6: US Space Command releases a radio message to all data network recipients announcing the dates of the exercise. This ensures that all data recipients are aware that exercise traffic will be broadcasted.

STEP 7: During the exercise, the TES elements provide TBM voice warning to the warfighting CINC headquarters over a First Detect/First Report telephone conference. The MWC acts as net control and provides a summary confirmation of the TBM events on this conference. The CINC headquarters is then responsible for relaying the warning to the theater users. After terminating the conference, the MWC then provides an event verification call to the CINC headquarters.

STEP 8: Simultaneously with Step 7, the TES elements release TBM data reports.

DATA EXPLOITATION INITIATIVES AT THE SWC

MSgt Jim Weaver, SWC/AIA Support Branch DSN 560-9952

Several data exploitation initiatives have been rolling since the beginning of the fiscal year. Some of these efforts are categorized under the intelligence discipline of Measurement and Signature Intelligence (MASINT). MASINT is the often misunderstood and relatively under-utilized (except in the infrared spectrum) intelligence discipline which shows a lot of promise with the improved communications and processing capabilities of the 90's. TALON SHIELD and TALON VISION are driving projects which will change the way existing systems and data are perceived and exploited.

Low Intensity Special Event (LISE). Low Intensity Special Event (LISE), pronounced "Lisa" to avoid the parasitic preconceptions of the plural noun of louse, is a proof-of-concept initiative in TALON SHIELD for improving monitoring of nuclear detonations, providing a secondary source to support infrared observations, and detecting other natural or man-made flash events. TALON SHIELD performs research and development taking advantage of its unique capability to receive all on-line Defense Support Program (DSP) satellite data. LISE processing, developed by the Department of Energy's Sandia National Laboratories, captures real-time data, extracts mission data and telemetry, and performs analysis which will eventually augment the current short wave infrared analysis. The overall objective of this special signal processing is to improve missile warning and nuclear treaty monitoring. The data which is extracted has in the past been used only for sensor state-of-health analysis but with this new process can be used to reconstruct low intensity signals present in the visible spectrum on the earth disc.

Unmanned MASINT Sensor (UMS). The "ummmms" is a sensor being developed by the Central MASINT Technology Coordination Office (CMTCO) located at Patrick AFB, Florida. This new sensor provides the capability to extract acoustic and seismic data from the surrounding tactical environment. TALON SHIELD is exploring the options available for dissemination and exploitation of sensor data while coordinating with CMTCO the options for utilizing the Generic Area Limitation Environment (GALE) capability for both mission planning and analysis. Integration of UMS at TALON SHIELD will prove the capability for improving both indications and warning and situational awareness.

Project Advanced Concept MASINT Exploitation (ACME). This TALON VISION proposal for FY97 will demonstrate the applicability of MASINT data exploitation technologies to meet warfighter requirements. Based on recent achievements of US Space Command and the National Air Intelligence Center during ROVING SANDS 95 Project Night Vector, this effort will exploit the capability of processing specialized radar data to produce unique products to users. This new capability will provide benefits such as improved battle damage assessment, theater missile deployment identification and location, and extension of the digital terrain elevation databases.

The Space Warfare Center, with the support provided by the 544th Intelligence Group, will continue efforts such as these to demonstrate improved capabilities for all the services as well as the intelligence community.

SATELLITE REFUELING: THE TACTICAL ADVANTAGE

Capt Don Ridolfi, SWC/DOT, DSN 560-9606

Flexibility is the key to Air Power *and Space Power*. How flexible is a satellite which cannot make timely or significant maneuvers without sacrificing useful operating life? Satellites operate today as airplanes did before aerial refueling; with limited scope and flexibility. Because, there are no space bases to service spacecraft, when a satellite runs out of fuel, its mission is over, whether we want it to be or not. Even the National Aeronautics and Space Administration (NASA) recognizes that the "Resupply of fluids on orbit will be a key element of future space operations." (6:1) One method to tremendously increase flexibility is to develop on-orbit satellite refueling.

The reasoning behind satellite refueling has often been limited to extending a satellite's life. Generally overlooked is the ability refueling provides to expand satellite employment concepts and remove limitations for their use.

Currently, fuel use limitations drive operational capabilities. Fuel load is planned based on an *expected* mission and launch vehicle lift capacity. Planners are prevented from developing operations concepts which would drive fuel requirements and satellite weight above the lift capacity of current launch vehicles. Additionally, once the satellite launches, the operations concept becomes difficult to modify in response to unforeseen circumstances.

Ideally, operational considerations should drive fuel use. Fuel is normally rationed and optimized based on the satellite operations concept. Satellite orbital adjustment maneuvers are limited to those essential for mission survival only. Because of finite fuel capacity, satellite operators usually will not perform a maneuver that was not planned as part of the original operations concept, even if the maneuver would enhance mission performance. Frequently, this means users have to wait to get needed support or not get it at all. On-orbit refueling is an excellent way to overcome fuel use limits. Additionally, satellite refueling enhances "space support to the warfighter" by improving the ability to provide timely support to warfighter needs.

The United States should develop on-orbit satellite refueling to enhance our ability to use satellites tactically. Currently, the ability to maneuver satellites is limited by the amount of fuel they carry. Maneuvering a satellite reduces a satellite's useful life and some maneuvers are impossible because of insufficient fuel. When its fuel runs out, the satellite must be replaced, often at great expense. In a tactical environment, finite fuel capacity limits mission options and capabilities. This situation requires a total change to the satellite concept of operations. Refueling provides the ability to use satellites with fewer constraints, enhancing mission accomplishment.

SCOPE: This discussion is limited to assessing the need to refuel satellites. It does not address either cost effectiveness or refueler vehicle design.

ASSUMPTIONS: NASA studies show that refueling spacecraft is feasible, "would allow for extended spacecraft utilization" (10:636) and could "be implemented without significant complexity." (5:10) NASA also developed the basic concepts for automatic vehicle rendezvous and fluid transfer. (10:636) Rockwell International's Space Systems Division developed detailed concepts for "automated and/or robotic resupply of consumables on orbit." (8:407)

Space Shuttle experiments attempted and successfully demonstrated zero gravity fluid handling and transfer on mission STS-53 in Dec 92 (6:1) and achieved above 95 percent tank fill levels with no loss overboard on mission STS-57 in Jun 93 (7:1). From these and other experiments, NASA concluded that liquid transfer is possible in space using "remote commanding or automated sequencing." (5:10)

Based upon these studies and experiments, it is logical to assume: (1) Refueling is possible via the Space Shuttle or Expendable Launch Vehicles; and (2) Technology for manned or automated (robotic or remote

control) refueling is possible.

Given these assumptions, it is also reasonable to assume: (3) Refueling of all orbits including geosynchronous is possible. Simplisticly, *if you can launch there, you can refuel.*

Advantages

Satellite refueling significantly increases tactical flexibility, speed, and responsiveness. The ability to maneuver with fewer restrictions imposed by limited fuel would greatly enhance our ability to gather information quickly. The Toffler's, award winning "Futurist" authors of *"War and Anti-War: Survival of the Dawn of the 21st Century", "Future Shock"* and *"The Third Wave",* view information as vital to future conflicts. "A small bit of the right information can provide an immense strategic or tactical advantage. The denial of a small bit of information can have catastrophic effects." (13:148) By maneuvering to modify its orbit, a satellite could take less time to accomplish some missions limited by orbitology (e.g., satellite revisit time). Hence refueling provides the ability to gather information faster than would otherwise be possible.

Limited flexibility is exemplified by Global Positioning System (GPS) satellites. Should a GPS satellite fail unexpectedly, under current capabilities, it may be difficult to replace. Due to satellite power and attitude control restrictions, access to each GPS constellation orbital plane is available during limited times each year. (11:—)* Additionally, the satellites simply cannot move between planes because a plane change maneuver would use all of the satellite's available fuel effectively killing the satellite. (11:—) While waiting for a replacement satellite, the GPS constellation's ability to provide accurate position data to users is degraded. Refueling capability for GPS would make it possible to maneuver a replacement satellite to the proper position in the constellation regardless of the time of year.

Additionally, Major General Vesely, 14AF/CC endorses the idea of reconfiguring the GPS constellation to optimize coverage of a specific area. (15:—) During Desert Shield, operators moved a GPS satellite between two of the GPS constellation's orbital planes. While this maneuver enhanced coverage of the Middle East, it reduced the satellite's life. (11:—) Satellite refueling makes this optimization possible without sacrificing spacecraft lifetime.

NASA reports another benefit of satellite refueling is extending satellite life. (1:415) Currently, if a satellite's orbit is less than optimal because of an errant launch, then operations fuel is used to maneuver the spacecraft to a usable orbit. Refueling would mitigate the loss of satellite life. Extending a satellite's useful life would also save the extensive time, cost, and manpower needed to prepare a new satellite.

Replacing fuel also reduces the limitations imposed on satellite maneuvers. For example, refueling would allow faster orbital position changes for Defense Support Program (DSP), Defense Satellite Communications System (DSCS), and other geosynchronous satellites by significantly reducing drift time to a new location.

Additionally, satellite refueling improves satellite maneuverability and increases its survivability. Currently, a satellite's ability to maneuver to avoid an antisatellite weapon attack is constrained by the fuel the target satellite carries. With refueling, the satellite could maneuver to evade a threat almost indefinitely.

NASA also expects satellite refueling to "improve spacecraft supportability." (5:1) A satellite refueling vehicle could provide the ability to replace a target satellite's damaged orbital replacement units, (1:415) deliver cryogens and other consumable fluids and gasses, or power (e.g. recharge batteries). (9:121) Using modular design for future satellites will simplify repair and upgrade making a refueling mission even more attractive.

Achieving the capability to refuel satellites will be an expensive proposition. However, the nation must pursue it in order to gain and maintain "information superiority." In future conflicts, "information superiority" will be a key element of success. (13:230) By developing the capability now, it will be available when needed.

Disadvantages

Costs and problems associated with the development of additional technology and the redesign of satellites to accommodate refueling can be perceived as a large risk of resources. A Japanese conference paper

noted however, "Although the economic benefits of [satellite refueling capability] are initially outweighed by the cost associated with [technology] development, [satellite refueling] can eventually make satellite resources more efficient." (16:—) As with all Research and Development, refueling technology is an investment in the future. The capability to refuel satellites will be instrumental in gaining space control while failure to develop refueling technology will impose severe limits on the use and control of space.

Despite the cost of developing this technology, there is the potential it would not be used. The expense of refueling missions could prompt a reluctance to use the capability or the situations envisioned for refueling might not occur. Thus a large investment in development and infrastructure would be wasted. Given the importance of space to future terrestrial operations, however, this seems highly unlikely.

An additional danger is possible satellite/mission loss or degradation due to failure to successfully refuel. This includes refueling mission launch failure or loss of the satellite because the refueler vehicle was unable to separate from the satellite. (9:126) Also, any failed attempt to refuel may delay satellite replacement extending the time the mission is affected.

FACTORS BEARING ON THE PROBLEM

Limitations Imposed By Current Launch Capabilities

The consistent ability to launch on schedule or as needed will affect our ability to perform refueling operations successfully. Other factors including the locations and number of launch pads available, the launch rate, launch cost for the various launch vehicles, and launch success rate impact the capability of a refueling program. Also, refueling launches would place additional demands on the nation's already limited launch capability and compete directly with current planned satellite launches. Until the nation develops increased launch capacity, refueling operations may be difficult to support.

Possible Solar Environment Effects On Satellites

The solar environment has the potential to affect satellite orbits. This could require increased maneuvering to overcome any orbital perturbations. The Space Forecast Center reports, "Since solar activity is closely correlated with the number of sunspots, solar events and operational impacts also tend to follow [the solar] cycle." (4:2-1) Approaching solar maximum, the general level of solar activity increases. This activity heats and expands the Earth's upper atmosphere causing increased drag for low earth orbiting satellites. As an example, increased atmospheric drag caused Skylab to reenter the atmosphere prematurely. (14:2-19, 2-20) Refueling a satellite would increase the amount of fuel available for maneuvering to overcome atmospheric drag, prolonging spacecraft life.

Increased solar activity can also cause more frequent satellite disorientation. (4:4-1) To correct this problem, the satellite would have to maneuver more often. This increased maneuvering would use fuel faster decreasing satellite life. Refueling the satellite would provide more fuel to combat the effects of satellite disorientation.

Anticipated Need To Refuel Satellites

During war or a crisis, there is an increased need for the information which satellites can provide. This need can prompt increased satellite maneuvering and therefore, fuel use. The increasingly complex world situation dictates a greater reliance on satellite capability. Refueling satellites will provide this capability without either sacrificing or replacing satellites due to fuel depletion.

Satellite Refueling Situations

Each satellite program will derive different benefits from refueling. Refueling decisions must reflect the optimal solution for each system. Low earth orbiting satellites, for example, usually require more maneuvering

than satellites in other orbits. This increases the value of refueling for satellites in low earth orbit. Alternatively, a satellite's operating cost might make it more cost effective to replace the satellite rather than refuel it. However, the availability of a replacement satellite could also affect the decision to refuel. Also, a newer model satellite with upgraded technology could prove more desirable. Program managers should consider these tradeoffs on a case-by-case basis.

Because of Spacecraft maneuver limits (fuel use is rationed and optimized), other satellite components can become life limiting. This degradation may make it impractical or impossible to refuel. In that instance, extending the satellite's life does not make sense unless it can also be repaired. To illustrate, Defense Meteorological Satellite Program (DMSP) components are relatively short lived, (12:640) making it impractical to refuel. However, by repairing the components or designing them to be more robust, refueling becomes a viable option.

Finally, satellite refueling is an inherently dangerous operation. A possible mission loss or degrade could occur if hydrazine or another toxic substance was released, contaminating the satellite's sensors or personnel performing extra vehicular activity. (3:627) However, the risk of refueling mishaps can certainly be reduced to acceptable levels as with terrestrial refueling operations.

POSSIBLE SOLUTIONS AND TRADE-OFFS

There are several ways to improve satellite maneuverability, increase life, etc. A recent Air Force study identified several methods to achieve these objectives. (12:639-655) The study discussed using more robust satellites launched with a bigger booster as well as various ways to employ refueling on-orbit. DMSP, DSCS, DSP, GPS, and the now canceled Space Based Radar were included in the study. Conclusions were based on assumptions (weight of refuel capability, minimum fuel, etc.), individual satellite parameters, and costs. Decision criteria were economically based. (12:639-655) The study determined geosynchronous satellites, especially if moved frequently or over large distances, were cost effective. (12:653) Low flyers like the Space Based Radar were also considered cost effective. These satellites periodically maneuvered to overcome drag and cost to refuel was much less than the satellite procurement and operations costs. (12:642) However, this study did not consider the potential that tactical maneuvering could be more important than cost considerations.

Use A Larger Launch Vehicle Without Refueling

One of the options considered by the Air Force study was using a larger booster without refueling the satellite. In this situation, additional mission hardware, redundant components and/or extra fuel are used to increase satellite capability. (12:639) This method avoids the problems and complexity posed by satellite refueling but does not increase its ability to maneuver. Refueling a satellite would extend its life while also providing the flexibility to maneuver as much or as little as desired. Without it, satellite maneuvers are limited by a finite fuel capacity.

Refuel On-Orbit

Future satellite concepts of operations could include planned refueling or simply the ability to refuel if needed (e.g., in a crisis). In either case, additional fuel could be pre-positioned on-orbit or launched when needed.

Various options for taking advantage of a refuelable satellite exist. Some of these include reducing launch weight, increasing payload, and using a smaller or larger launch vehicle. (12:639-655) Given a refuelable satellite, engineers can then choose the optimal mix of fuel, payload and launch vehicle based on mission requirements.

Refueling Methods

There are several methods to perform on-orbit refueling. Each method can be performed by a robot, remote control or by astronauts. (5:10;6:1)

Rockwell International investigated concepts for resupply of consumables on-orbit using liquid transfer, tank transfer, and propulsion system transfer methods. (2:1426) The liquid transfer method involved moving fuel only between the refueler and target vehicle. This method had the least impact on vehicle design but took longer to complete and raised more safety concerns than other methods investigated. Rockwell concluded this method was the most cost effective and feasible. (2:1426)

The tank transfer method involved moving whole fuel tanks between the refueler and target vehicles. Rockwell found this method took less time than liquid transfer, however it wasted fuel because the transfer had to be performed before the tank was completely empty. The disadvantages of this method included reduced cost effectiveness because of the wasted fuel and a weight penalty for the refueler vehicle. Other drawbacks included additional design constraints for the capability to exchange tanks and a shift in the vehicles' center of gravity during tank transfer that raised concerns for vehicle stability and controllability (2:1426)

The last method considered by Rockwell, was propulsion system transfer. This method involved moving all propulsion system components between the refueler and target vehicles. The disadvantages of propulsion system transfer were the same as those for tank transfer but were more pronounced. (2:1426)

The final method considered involves a relatively large service station or tank in space with a smaller servicer vehicle to refuel satellites. (2:1426) One type of servicer vehicle, called a Space Tug, could refuel and repair satellites as well move them to their final orbit. (15:—) A manned servicer vehicle NASA studied would be capable of servicing geosynchronous satellites. (1:415) This servicer concept would be especially useful for satellite repair or in orbits where a large fuel supply is needed because of frequent refueling. The servicer vehicle would move only the fuel needed and thereby avoids having to move the entire mass of the service station.

CONCLUSIONS AND RECOMMENDATIONS

Satellite refueling capability is essential for future operations in space. It can provide the ability to gather information faster, extend satellite life, reduce limits on maneuvers, and increase the survivability and supportablity of all satellites. These capabilities would increase flexibility to support tactical operations by providing additional options for mission accomplishment.

The decision to develop satellite refueling capability must be based on the tactical benefits it produces. Costs and technical obstacles, including the nations limited launch capability, are considerations in this decision. However, in a crisis, mission accomplishment is more important than cost effectiveness. Additionally, this capability must be developed now, so it is available when needed.

While it is possible to acquire additional satellite capability by using a larger launch vehicle, refueling satellites on-orbit provides the most options to achieve mission objectives. Of the satellite refueling methods considered, fluid transfer and an orbiting service station with a servicer vehicle appear to be the most promising.

Should the United States develop on-orbit satellite refueling to enhance our ability to use satellites tactically? The answer is a resounding, yes!

BIBLIOGRAPHY

1. Budinoff, J., et al. MOOSE: Manned On-Orbit servicing Equipment, NASA-CR-197151, 1993.
2. Clarke, Margaret M., et al. Robotic On-Orbit Fueling of SEI Vehicles, Engineering, Construction, and Operations in Space III: Space '92; Proceedings of the 3rd International Conference, Denver, CO, May 31-June 4, 1992.
3. Cross, J. H., Beck, S. W., and T. F. Limero. Hydrazine Monitoring in Spacecraft, 5th Annual Workshop On Space Operations Applications and Research, 1991.
4. Department of the Air Force. AFSFCP 105-3, Guide to Space Environmental Effects on DOD Operations, 27 April 92.
5. Distefano, E. Advanced Liquid Feed Experiment, 29th AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, Monterey, CA, June 28-30, 1993.

6. Dominick, Sam. Fluid Acquisition and Resupply Experiment (FARE-I) Flight Results, 29th AIAA, SAI, ASME, and ASEE, Joint Propulsion Conference and Exhibit, Monterey, CA, June 28-30, 1993.
7. Dominick, Sam, and James Tegart. Orbital Test Results of a Vaned Liquid Acquisition Device, 30th AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference and Exhibit, Indianapolis, IN, June 27-29, 1994.
8. Manoucheri, Davoud, and A. J. Mauceri. Automated Resupply of Consumables: Enhancement of Space Commercialization Opportunities, 5th Annual Workshop on Space Operations Applications and Research, 1991.
9. Milton, Martha E., and Tony R. Tyler. Development and Testing of the Automated Fluid Interface System, the 27th Aerospace Mechanisms Symposium, May 1993.
10. Moore, James S. On-Orbit Refueling Abstract Only, Sixth Annual Workshop on Space Operations Applications and Research, 1992.
11. 2d Space Operations Squadron Mission Briefing and Operations Center Tour, 29 Aug 95.
12. Smith, Scott. Preliminary Analysis of the Benefits Derived to US Air Force Spacecraft From On-Orbit Refueling, Sixth Annual Workshop On Space Operations Applications and Research, 1992
13. Toffler, Alvin and Heidi. War and Anti-War: Survival at the Dawn of the 21st Century. Boston: Little, Brown and Company, 1993.
14. Vanguard Research, Inc., and ARINC Incorporated. Space Weather Training Program Student Manual, 16 June 95.
15. Vesely, David L., Major General, USAF, 14 AF/CC. Personal Interview, 13 Oct 95.
16. Yasaka, Tetsuo, Yasui, Yoshitsugu, and Shun-Ichi Oda. Abstract : On Orbit Servicing and Its Implications On Future Geostationary Activity Growth, Proceedings of the International Symposium on Artificial Intelligence, Robotics and Automation in Space, Kobe, Japan, Nov 18-20, 1990.

**(NOTE: Clarification provided by Mark Drake, Payload Analyst, Rockwell Spae Coperations, 30 Jan 96.)*

76th SPACE OPERATIONS SQUADRON

Lt Col Tom Meade, 76 SOPS, DSN 560-9608

The 76th Space Operations Squadron activated at the National Test Facility at Falcon Air Force Base, Colorado as a component of the 14th Air Force on Dec 1, 1995.

The ceremony included the redesignation of the 76th Fighter Interceptor Squadron as the 76th Space Operations Squadron, its reactivation, and the assumption of command by Lt Col Thomas L. Meade.

Major General David L. Vesely, Commander, 14th Air Force, Vandenberg AFB, CA, officiated.

The mission of the 76th SOPS is to assist air component commanders in understanding and applying space systems in support of air operations. The unit ensures that command and control, communications, weather, navigation, and other space assets are used to most effectively multiply US and allied combat forces capabilities against an adversary.

The squadron's Air Force Space Support Teams will be deployed during crises and contingencies worldwide to provide space expertise and support to warfighters, anytime, anywhere.

Originally the 76th was constituted as the 76th Pursuit Squadron in 1941. It was activated as the 76th Fighter Interceptor Squadron in 1955, and operated from bases in Maine, Florida, Massachusetts, Louisiana, and North Carolina flying combat training missions until it deactivated in 1963.

In 1972 it was reactivated as the 76th Tactical Fighter Squadron at England AFB, LA. After playing an important role in Desert Shield and Desert Storm, it was deactivated in 1992.

SPACE 101 - PRINCIPLES OF SPACE OPS

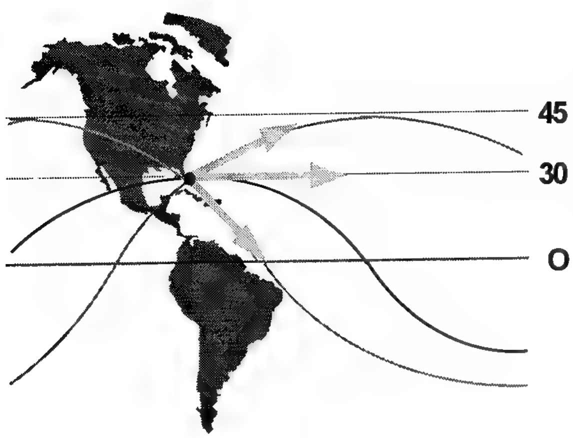
SSgt Kurt Reynolds, SWC/DOT, DSN 560-9711

Here we are once again with more basic principles of space operations. In our Fall 95 bulletin, we discussed and defined the terms that are used to describe orbits (element sets). In this issue, we will turn our focus to spacelift principles.

In the execution of a successful space launch, many things will have been accomplished to a very high degree of accuracy. From the time boosters and satellites are built they will go through seemingly endless processing and systems checks before any launch can take place. Since this processing is very technical and complex, it will not be covered in this article. Instead we will examine basic concepts and terms associated

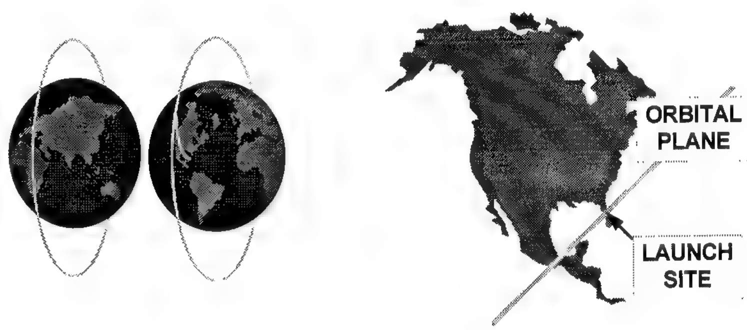
with space launch operations as they relate to achieving a specific orbit.

In order to consider a launch to be successful, the payload must have the correct speed, altitude, and direction at booster burnout. If any of these are not correct, we have not achieved a successful launch. Lets say that we are launching a satellite from Cape Canaveral AS that is to go into a low earth orbit (100 mile altitude). Our booster must be capable of lifting the weight of our satellite off of the pad and achieving an altitude of 100 miles. That doesn't sound like much does it? After all, it only took a truck to move our satellite thousands of miles to the launch site! The tricky part is that we must be able to roughly match the curvature of the earth at the desired altitude and accelerate the satellite to an orbital velocity of 17,500 miles per hour. If we nailed it, we have achieved two of our three objectives; altitude and speed.



Launch Azimuth

We must also pay particular attention to the direction, or azimuth, that we take from the launch site as it will have a profound effect on our satellites orbital inclination (i.e., by launching due east (90 degree azimuth) you achieve an inclination equal to the latitude of your launch site). We want to place our satellite in an inclination of 30 degrees. Since the latitude of our launch site is 30 degrees, we will launch to a 90 degree azimuth (this will make 30 degrees the northern most latitude that the satellite will pass over and because all orbital planes include the center of the earth, 30 degrees will be the southern most latitude passed over). If we launch north or south of due east, we go into an inclination greater than 30 degrees. Another way to phrase it is "The lowest inclination you can launch directly into is equal to the latitude of your launch site." If we're successful, we have added the third element of a launch, direction.



Launch Window

This brings us to an important term used in launch operations called a Launch Window. Contrary to some popular beliefs that a launch window is an imaginary rectangle in the sky that we have to fly through, it is actually the amount of time that we have to launch directly into a certain inclination. Our desired orbit is described by a stationary ring around the earth. The earth is constantly spinning (15 degrees every hour) under this ring. At some point the earth's rotation will carry our launch site directly under the ring. If our chosen booster has only enough fuel to place our satellite into the desired orbit, we have to launch the instant we pass under our desired inclination. That would be poor planning on our part. Better would be to have excess capacity on our booster beyond the weight of our satellite so that we could launch well before or after we pass under our inclination. We then would have a window of time (launch window) in which we could launch, early or late, and still fly the booster into our desired inclination. For instance, the typical launch window for Delta boosters launching GPS satellites from CCAS is 40 minutes (i.e., they can launch up to 20 minutes before or after they're under the desired inclination).

The number of opportunities you will have to launch directly into a certain inclination each day will depend on the location of your launch site and your desired inclination. If your desired inclination is greater

than the latitude of your launch site, you will have two opportunities per day to conduct the launch. The earth's rotation will carry you under the inclination at one point and then 180 degrees (or 12 hours) later will carry you under it again. If your desired inclination is equal to your latitude, you'll have one opportunity per day. If your desired inclination is less than your latitude, you will never have a direct launch opportunity. You will be forced to launch to the lowest possible inclination and then maneuver the satellite to the desired inclination.

Space systems will continue to play an increasing role in all facets of military operations. Since knowledge is one of your best weapons, we cordially invite you to sign up for our Space and Missile Applications Basic Course (SMABC), *the ABC'c of space.* You'll get two days of space fundamentals, like the above, covering the entire range of space applications. Additionally, we also teach the Space Applications Advanced Course (SAAC). These courses can be taught at your location or here at Falcon AFB. Simply contact our registrars at DSN 560-9640/9645. *Note: Senior SMABC/SAAC classes are in the process of being merged into one course in the future months.*

Tentative Schedule for SMABC

27-28 Mar 96	Staff SMABC	Peterson AFB, CO
8-12 Apr 96	Sr SMABC	Colorado Springs, CO
7-8 May 96	Staff SMABC	Peterson AFB, CO
3-7 Jun 96	CONUS Road Show	LA AFB, CA
24-28 Jun 96	CONUS Road Show	LA AFB, CA
13-14 Aug 96	Staff SMABC	Peterson AFB, CO
16-27 Sep 96	Overseas Road Show	PACAF

Tentative Schedule for SAAC

8 Apr 96	Falcon AFB, CO
3 Jun 96	Falcon AFB, CO
5 Aug 96	Falcon AFB, CO
7 Oct 96	Falcon AFB, CO

Editors Note: This is the last article authored by SSgt Reynolds. He will be PCSing to 14th AF at Vandenberg AFB in January 96. Capt William Vogt will be the new author of this article. He can be reached at DSN 560-9653.

Index 96

SWC Space Tactics Bulletin

The Space Tactics Bulletin Master Index is provided in each Winter issue as an aid to completing your reference library. The articles are listed by title. The index includes all articles published since the inception of the Space Tactics Bulletin. Limited back issues are available upon request. For our address, see the inside cover.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AIR FORCE SPACE COMMAND

FROM: Space Operator

SPACE WARFARE CENTER

GRADUATE

USAF SPACE TACTICS SCHOOL

TO: Warrior